Saskatchewan Technology Enhancement Program

Updating of the Wynyard (72P) Land Use Map Using Landsat Digital Data

by

Patricia M. Beaulieu
Wildlife Branch
Saskatchewan Parks and Renewable Resources
Hudson Bay, Saskatchewan

SRC Technical Report No. 194
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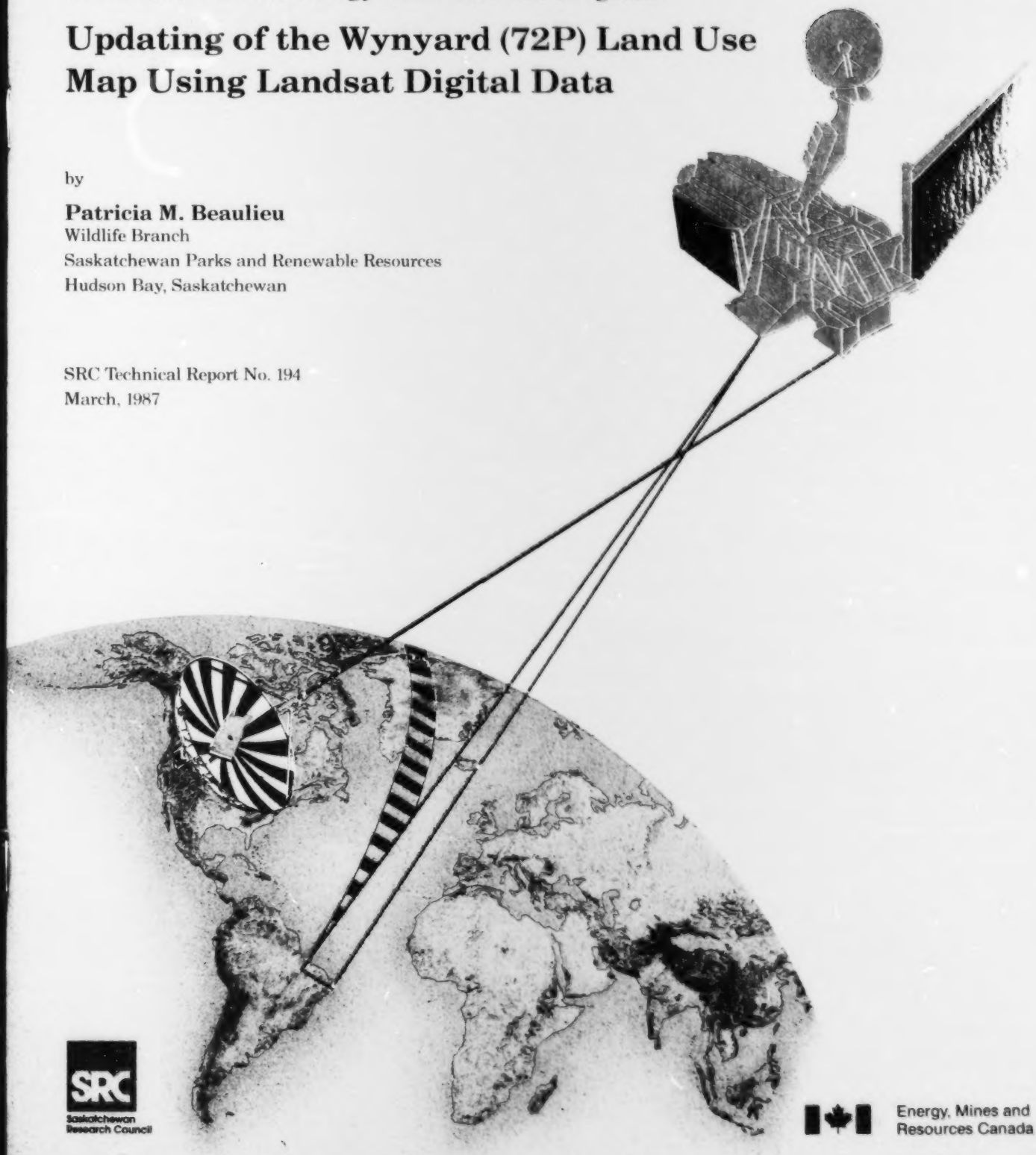

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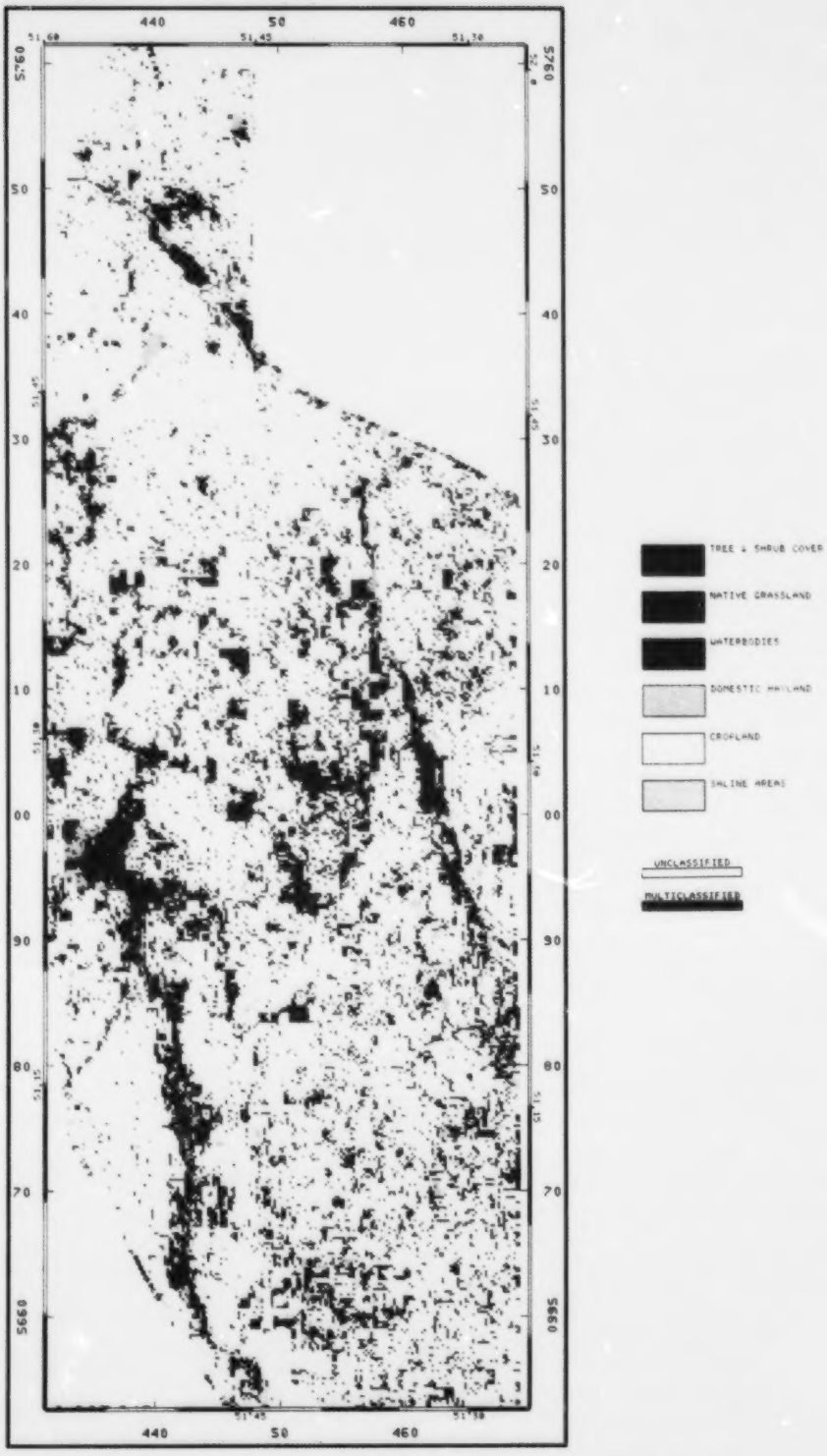

WYNYARD AREA ZONE 22

LAND USE MAPPING-TECHNOLOGY PROJECT LANDSAT IMAGERY-JUNE 3,1984
P.H. BEAULIEU-S.P.B.D. WILDLIFE BRANCH

SCALE 1:250000

Map 2. Map from Digital Data Analysis - Wynyard Map Area - WMZ22.

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ABSTRACT

The Department of Parks and Renewable Resources, Wildlife Branch, prepared land use maps of the agricultural areas of Saskatchewan under the Terrestrial Wildlife Habitat Inventory (TWHI) project. However, the maps were decreasing in usefulness because they were going out of date. In an attempt to update them the Wildlife Branch embarked on a pilot project in cooperation with the Saskatchewan Technology Enhancement Project (STEP). The objective of the project was to create a new land use map of the study area based on an analysis of digital Landsat multi-spectral scanner data. The advantages and refinements of remote sensing technology are compared to traditional methods of air photo interpretation and an evaluation of speed and accuracy of the technology was assessed.

ACKNOWLEDGEMENTS

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1. INTRODUCTION

1.1 Background

Between 1975 and 1984 the Wildlife Branch of Saskatchewan Parks and Renewable Resources (SPRR) mapped land use, land tenure, land systems and critical wildlife habitat for each of the 21 (1:250,000) map sheets in the agricultural areas of Saskatchewan under the Terrestrial Wildlife Habitat Inventory (TWHI) project. Although the project was successfully completed, it became apparent that many of the maps would need to be updated. It was ascertained that to use air photo interpretation, as used to produce the original maps would be too costly, and be overly time-consuming. In addition, new aerial photography would have to be obtained as a prohibitive cost.

In January 1985 a Memorandum of Understanding for cooperation in remote sensing was signed between the Canada Centre for Remote Sensing (CCRS), Energy Mines and Resources, and the Saskatchewan Research Council (SRC). The agreement, the Saskatchewan Technology Enhancement Program (STEP), was a cooperative undertaking whereby CCRS loaned a Aries[1] II image analysis system, and provided the full time services of a remote sensing specialist to assist in using the system and to advise cooperating principal investigators. The STEP was to be completed in June 1987. A portfolio of joint projects was undertaken by a number of Saskatchewan government agencies at no cost for computer time or training of personnel. The image analysis system was installed at the SRC laboratories in Saskatoon by January 1985. Work on the pilot projects commenced at the same time.

As part of the portfolio the Wildlife Branch undertook a project of creating an up-to-date land use map using LANDSAT MSS digital data. However, it was both impractical and unnecessary to update all four maps (land use, tenure, systems and critical wildlife habitat) in the series. Since virtually all critical habitat occurred on native land, it was concluded that updating, the land use map, would yield information on the conversion of native lands to cultivation and therefore would, in effect, also provide information on loss of critical habitat.

1.2 Study Area

The Wynyard map area (72P) was selected as the study area because it was centrally located and had a diversity of native vegetation cover types. Lying between 51 and 52 north latitude, and 104 and 106 west longitude the study area was, in general terms, southeast of Saskatoon (Figure 1). The area was 15,440 km^2 and included portions of Last Mountain Upland, Touchwood Hills Upland, Allan Hills Upland, Quill Lake Plain, Assiniboine River Plain and Saskatchewan Rivers Plain (Acton et al. 1960).

The diversity of physiographic regions ensured a corresponding diversity in topography and native vegetation. The three native cover classes of primary interest in the project were the grasslands, shrublands and wooded areas. Large expanses of agricultural land, primarily cropland and hayland, were also included.

Native grasslands were dominated by wheat grasses (*Agropyron* spp.), blue gramma (*Bouteloua gracilis*), blue grasses (*Poa* spp.) and spear grass (*Stipa comata*), together with the

1) Mention or failure to mention commercial trade names doses not imply endorsement or criticism by the Government of Canada or the Government of Saskatchewan.

forb pasture sage (*Artemisia frigida*). In rolling topography the sheltered slopes support shrub stands consisting of snowberry (*Symphoricarpos occidentalis*), rose (*Rosa* spp.) and silverberry (*Elaeagnus commutata*). Deeper depressions, slough margins and ravines support tree cover in the form of trembling aspen (*Populus tremuloides*) and willow (*Salix* spp.) together with shrub species such as chokecherry (*Prunus virginiana*), Saskatoon (*Amelanchier alnifolia*) and snowberry (Gradin and Flory 1982).

1.3 Data Sources

Digitial Landsat Multi Spectral Scanner (MSS) data as a computer compatible tape (CCT) were obtained June 3, 1984. To aid in analysis of these Landsat data, and to provide some means of comparison and evaluation, several additional types of data were involved. These were from Lower Inventory for Tomorrow (LIFT) air photos from 1970, the TWHI Land Use Map based on 1978 data (Map 1 - page 15), and fieldwork which was done in September of 1985. Fieldwork involved a ground and an aerial survey in which topography, vegetation and soil types were described and photographed.

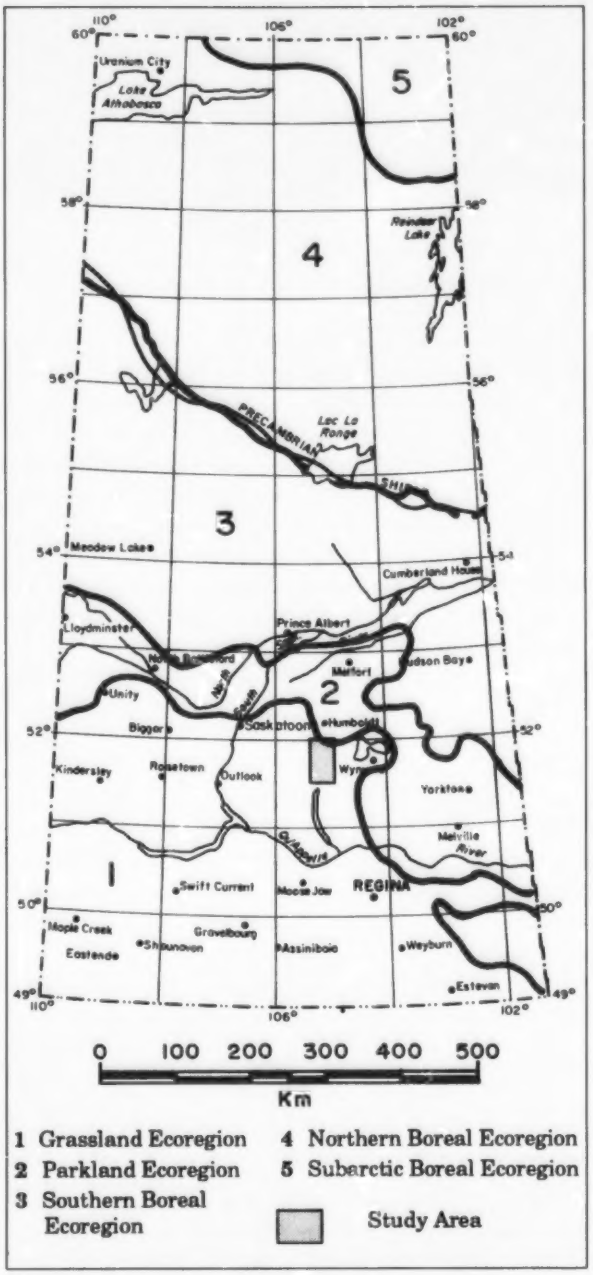

Figure 1. Location of Study Area.

2. OBJECTIVES

The objectives of the project were to:

1. Update the TWHI land use map of the Wynyard (72P) area with improvements where possible at 1:250,000 scale.
2. Subdivide the native vegetation classes into native pasture, shrubland and wooded cover.
3. Prepare a colour map of the vegetation classes.
4. Calculate the area of each cover class.

3. METHODS

3.1 Imagery Date

Both spring and fall satellite imagery had potential. In both cases because the croplands were dormant and the native woody vegetation were still in leaf the two classes were spectrally different. Photographic transparencies of the data for both seasons were obtained and examined for ease of separation between the native cover classes and cropland to determine if the native cover classes and cropland could be separated easily.

3.2 Digital Enhancement

Several types of enhancements were prepared on the image analysis system in order to improve the definition between native and domestic grasslands and among the three native cover classes. The following enhancements were used: log transformation, linear stretch, histogram equalization and a vegetation index enhancement.

3.3 Multi-date Imagery

To improve class separation, image to image registration of multi-date data for the study area was done.

3.4 Geometric Correction and Resampling of Image

Before any classification of the image could be made, the image had to be geometrically corrected to remove, among other things, the skew produced by the earth's rotation during imaging. At this time the data were also resampled so each pixel would represented a 50 m x 50 m surface area rather than a 60 m x 80 m rectangle. These two steps were performed early in the analysis to make visual recognition of landmarks and registration of images to maps easier.

3.5 Unsupervised Classification

An unsupervised classification was the first of two types of classification tested. By means of this algorithm a subarea of the entire image was divided into the number of classes which appeared to be spectrally different. Each of the classes was then visually examined and interpreted in relation to vegetation types. The operator then decided which classes could be combined and which should be classified further. After the number of classes has been optimised by this procedure, the classification was applied to the entire image.

3.6 Supervised Classification

Using supervised classification, the principal investigator used all background data available to choose the appropriate "training sites" of the same spectral signatures of the vegetation cover classes. A trial classification was then attempted for one subarea. The process was improved through the addition of more "training areas" in classes where confusion occurred. Finally the classification was applied to the entire image. The flowchart shows the steps plotted in detail (Figure 2). Note that there are several loops in this program where the accuracy of classification can be checked and improved.

3.7 Verification

The results of the classification were verified in a number of ways; visual assessment, comparison to ground and aerial survey data as well as to the TWHI land use map and 1970 LIFT aerial photos. Comparisons were also made to statistical data derived from the computer such

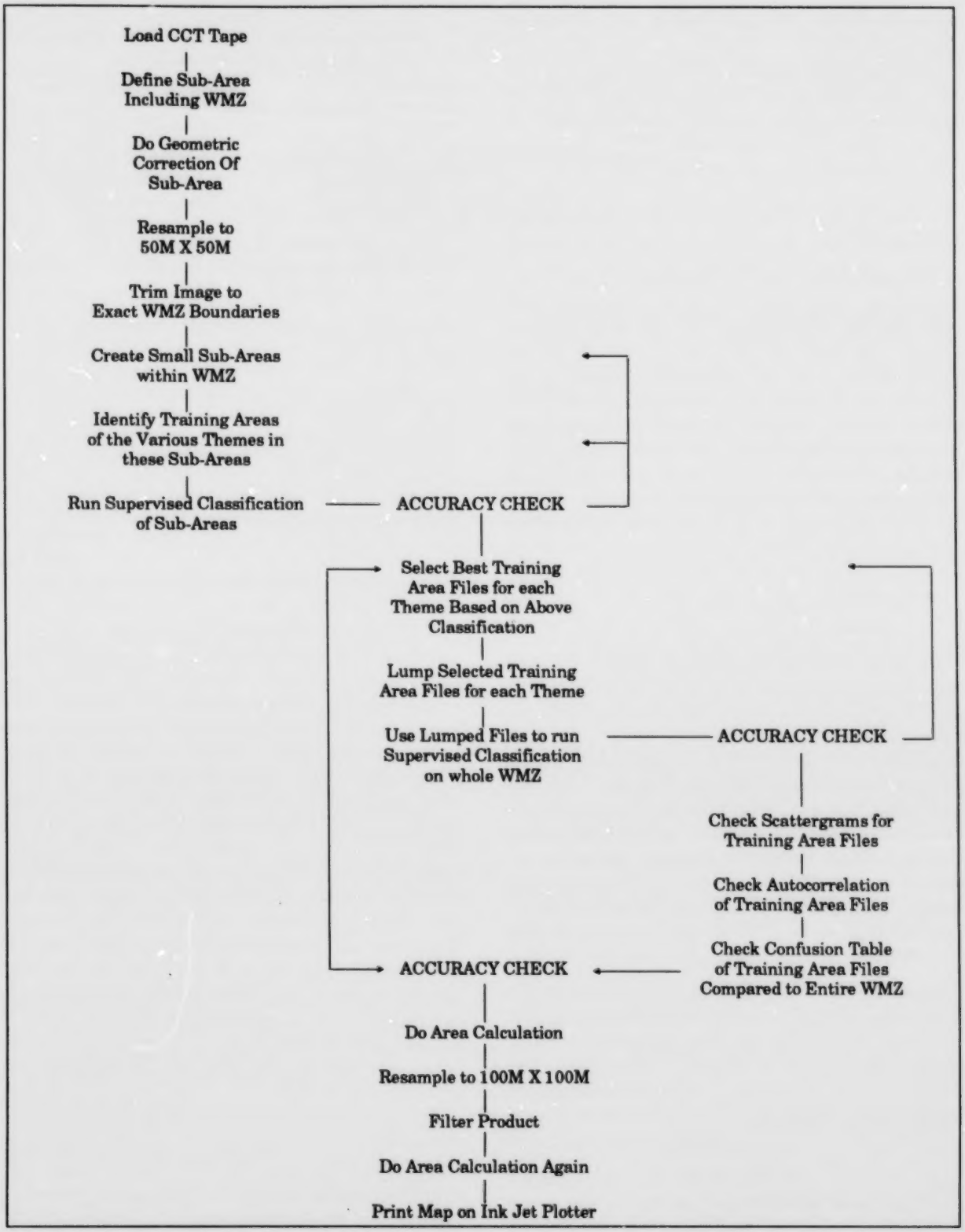
Load CCT Tape
Define Sub-Area Including WMZ
Do Geometric Correction Of Sub-Area
Resample to 50M X 50M
Trim Image to Exact WMZ Boundaries
Create Small Sub-Areas within WMZ
Identify Training Areas of the Various Themes in these Sub-Areas
Run Supervised Classification of Sub-Areas
ACCURACY CHECK
Select Best Training Area Files for each Theme Based on Above Classification
Lump Selected Training Area Files for each Theme
Use Lumped Files to run Supervised Classification on whole WMZ
ACCURACY CHECK
Check Scattergrams for Training Area Files
Check Autocorrelation of Training Area Files
Check Confusion Table of Training Area Files Compared to Entire WMZ
ACCURACY CHECK
Do Area Calculation
Resample to 100M X 100M
Filter Product
Do Area Calculation Again
Print Map on Ink Jet Plotter

Figure 2. Flowchart of Digital Data Processing.

as scattergrams, autocorrelation and classification similarity.

The final verification of the Landsat derived map was made by comparing the areal extent of cover to those of similar cover classes mapped in 1981. The 1981 data were taken from the Wynyard land use map produced by TWHI.

3.8 Hardcopy Map Production and Area Calculations

In order for the classified data to be reproduced in a map format at 1:250,000 scale the data was reduced by half. The data was also filtered to remove isolated, scattered theme pixels which were not significant. Each of the classes was filtered at a different level in order not to remove significant units within a particular class. This can be exemplified by small groups of trees covering 2.5 acres which were habitat areas and so had to be retained. Waterbodies of 2.5 acres in size were in many cases ephemeral and therefore not important, so the minimum size could be set at 5 acres (Table 1). Groups or individual theme pixels below the minimum size were absorbed into the surrounding cover class.

Table 1.
Cover Classes and Filter Factors for Wildlife Habitats of the Wynyard Area.

Class	Minimum Area After Filtering
Waterbodies	5 acres (2 pixels)
Tree and shrub cover	2.5 acres (1 pixel)
Native grassland	5 acres (2 pixels)
Domestic hayland	10 acres (4 pixels)
Cropland	15 acres (6 pixels)
Saline areas	7.5 acres (3 pixels)

After the final classification, area calculations were made of all cover classes of the non-resampled and unfiltered data as well as the resampled and filtered data.

4. RESULTS AND DISCUSSION

Because of the time required to become familiar with the image analysis system and the actual analysis of the satellite data the study area was reduced from the entire Wynyard map sheet of 15,440 km^2 to the Wildlife Management Zone 22 (WMZ 22) consisting of 3,228 km^2 in the western quarter of the Wynyard map sheet. Although the study area was reduced there remained sufficient physiographic features such as the Allan hills upland, the Saskatchewan River plain, the Assiniboine River plain as well as shrubland, forest, and grassland cover types to ensure a true representation of the total habitat.

Imagery from June 1984 was selected because it described the best separation between the native cover classes and cropland. The trees and shrubs were beginning to leaf out, but the grasslands and croplands had not yet greened up. Exceptions were fall rye and winter wheat which were green in spring and therefore caused some confusion with woody cover.

It was necessary to reduce the native cover classes from three (grassland, shrubland, tree cover) to two (grassland and tree cover). It was impossible to differentiate between tree and shrub cover since they leaf out at the same period of time and therefore have similar spectral reflectances. The grassland cover type contained small scattered shrub stands, making it difficult to separate from the shrubland community making it necessary to combine the two.

The attempt to do image-to-image registration of spring and summer data did not resolve the problem of confusion between fall rye and the wooded cover class.

The result of the unsupervised classification indicated that there was less spectral difference between hayland and native grassland than between summerfallow, stubble, and early spring crops. Therefore, the cropland class was divided into individual crop types while the hayland and native grassland cover types were combined. These results were therefore deemed unsatisfactory.

The results of the unsupervised classification provided the best separation between the various cover types and are dealt with on an individual basis.

Class 1 - Waterbodies. Although the method used was capable of accurately delineating both large and small waterbodies there was a known misclassification of cloud shadows as wetlands. Since clouds were erroneously classified as saline areas, wherever there was a combination of "waterbodies" with identially shaped "saline areas". This can be seen in the east central portion of the map (Map 2 - frontispiece).

Class 2 - Tree and Shrub Cover. Although the original intent was to separate the tree and shrub cover types, this proved impossible. There was also some difficulty in separating open shrubland from native grassland with scattered shrubs. Another misclassification of tree and shrub cover class occurred when the algorithm used combined all actively growing plant communities into this class, thereby including fall rye and winter wheat crops. This error is difficult to visually identify on the map, but can be seen as narrow strip fields of "trees and shrubs" in the lower left section of the map (Map 2).

Class 3 - Native Grassland. This category was mapped with a moderate degree of accuracy, with a problem in the gradation between grassland and shrubland which makes boundary definition difficult. Some stubble fields or weedy summerfallow strips were also misclassified as native grassland.

Class 4 - Domestic Hayland. Although some difficulties in classification were found in fields that converted from cropland to hayland, in general this classification was considered to

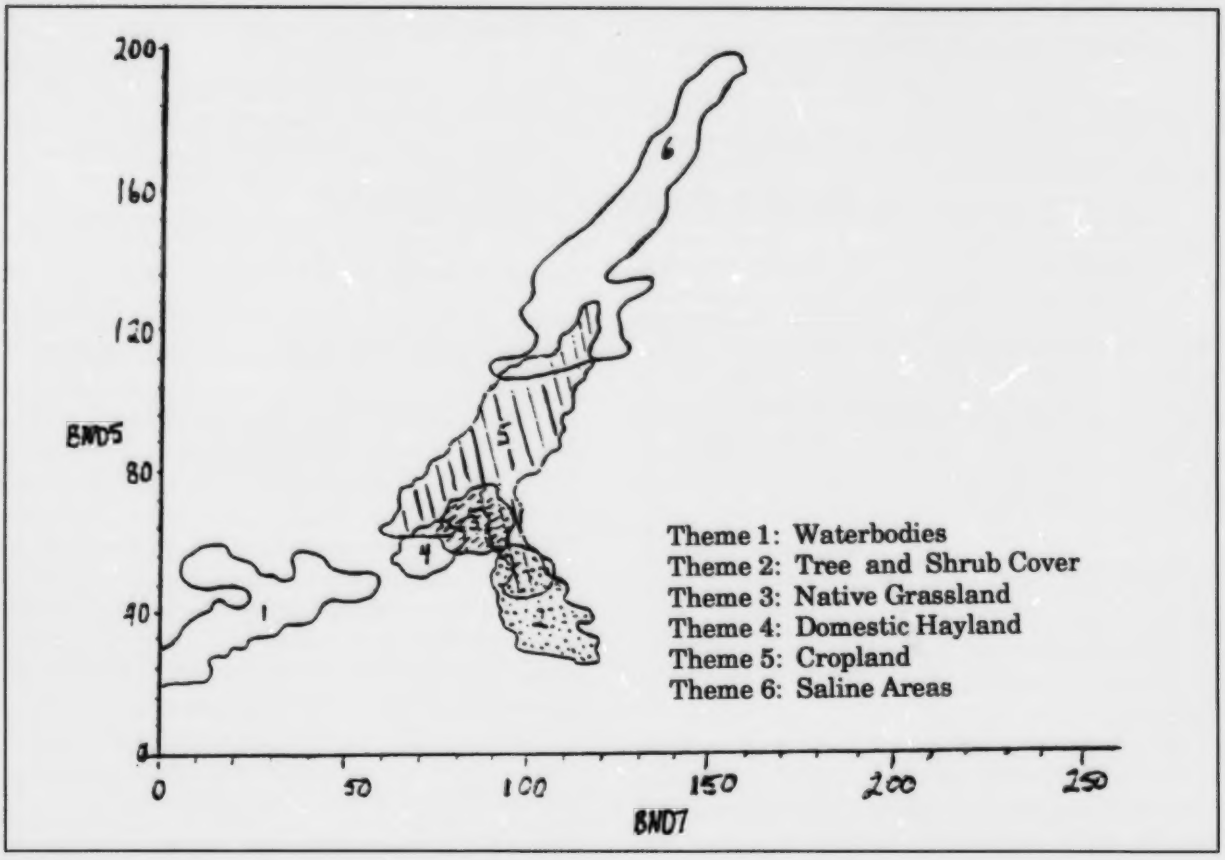

Figure 3. Scattergrams of All Classes, Based on Training Area Files.

Table 2.
Autocorrelation Table.

Class	Autocorrelation Distances Between Maximum Likelihood Signatures					
	1	2	3	4	5	6
1	0.0	16.3	11.4	7.7	8.9	11.9
2	16.3	0.0	5.3	8.9	7.8	11.4
3	11.4	5.3	0.0	4.5	2.2	5.9
4	7.7	8.9	4.5	0.0	3.1	6.5
5	8.9	7.8	2.2	3.2	0.0	2.4
6	11.9	11.4	5.9	6.5	2.4	0.0

Class 1: Waterbodies
Class 2: Tree and Shrub Cover
Class 3: Native Grassland
Class 4: Domestic Hayland
Class 5: Cropland
Class 6: Saline Areas

be accurate. Additional errors probably arose in fields that were native grassland but that had been cut or heavily grazed.

Class 5 - Cropland. This was a very difficult class to classify as it included stubble fields, summerfallow, freshly seeded fields, and early spring crops. There were some cases of confusion, particularly with respect to fall rye and winter wheat, as explained under Class 2 and 3, but in general, the classification was acceptable.

Class 6 - Saline Areas. Although this class included a relatively accurate delineation of saline flats and waterbodies, it also, unfortunately, includes all the scattered clouds (as described under Class 2) and, therefore, has a greatly inflated area.

Ground and aerial survey data, LIFT photos and the 1981 TWHI land use map were all used

Table 3.
Table of Classification Similarities Between the Five Cover Classes.

Class	1	2	3	4	5	6	Uncl.	Mult.	Accuracy
1	1746	0	0	6	4	0	235	0	87%
2	0	279	0	0	0	0	16	0	94%
3	0	10	1838	18	35	0	46	0	94%
4	0	0	10	518	6	0	12	0	94%
5	0	72	110	21	4186	49	114	0	91%
6	0	0	0	0	1	259	10	0	95%

Class 1: Waterbodies
Class 2: Tree and Shrub Cover
Class 3: Native Grassland
Class 4: Domestic Hayland
Class 5: Cropland
Class 6: Saline Areas

Table 4.
TWHI Land Use Data. Area of Land Use Classes (km^2). Wildlife Management Zone 22: Wynyard Map Area (Data from TWHI Map, Based on Manual Interpretation of 1978 Air Photos).

Land Use Class	km^2	Native Vegetation*	Cropland*	Hayland*
1	310.0	259.6		
1NT	6.3	3.8	18.4	72.5
1TN	33.9	12.3		
1T	18.7	2.3		
2	60.1	38.3		
2NT	8.7	4.0	24.8	11.9
2TN	12.2	3.5		
2T	1.7	0.2		
3	19.7	7.2	13.1	1.0
3NT	2.2	0.6		
4	2572.8	482.4	2058.2	32.2
5	166.2	8.3	157.9	0
Sub Total	3212.5	822.5	2272.4	117.6
Waterbodies	15.2			
Total Area of WMZ	3227.7			

*Calculated according to definition of land use classes, see accompany- ing section of TWHI land use map (Map 1).

to visually evaluate each of the enhancements and classifications by different algorithms. Raw data was therefore selected over digitally enhanced data, for supervised classification.

The first of these verification checks was the use of the scattergrams. Overlays of the scattergrams from each of the six cover classes (themes) is shown in Figure 3. Although there was some unavoidable confusion between similar classes, as noted above, in general separation between classes was good.

The results the autocorrelation test are presented in Table 2. Values above 2.0 indicate less than 10% correlation between the two classes. No two classes had greater than 10% correlation indicating that the training areas for each file were spectrally distinct and valid.

The classification similarities (or confusion table) results are shown in Table 3. There were few areas of confusion and none of these were major, resulting in a very high percent accuracy of classification of all classes (last column of table).

Table 5.
Classification Summary.

Class	Area (km^2)	Area (%)
a) Not Resampled or Filtered		
Waterbodies	54.6	1.7
Tree and Shrub Cover	90.3	2.8
Native Grassland	603.8	19.0
Domestic Hayland	98.4	3.1
Cropland	2303.9	72.4
Saline Areas	30.4	1.0
	3181.4	100.0
b) Resampled and Filtered		
Waterbodies	46.5	1.6
Tree and Shrub Cover	86.0	3.0
Native Grassland	548.7	18.9
Domestic Hayland	52.0	1.8
Cropland	2156.3	74.1
Saline Areas	20.2	0.7
	2909.7	100.1

Table 6.
Comparison of Area of Cover Classes Between TWHI Map (1978 Data) and the Landsat Map (1984 Data).

	TWHI Map		Lapdsat Map*	
	km^2	%	km^2	%
Native Vegetation	822.5	25.5	724.5**	22.8
Hayland	117.6	3.6	98.4	3.1
Cropland	2272.4	70.4	2303.9	72.4
Waterbodies	15.2	0.5	54.6	1.7
Total Area	3227.7	100.0	3181.4	100.0

*The data used for these calculations is from before the resampling and filtering processes, as this represents more accurate data for the classification used. Resampling and filtering were only necessary because of the resolution limitations of the Ink-Jet Plotter.

**Includes tree and shrub cover, native grassland and saline areas.

Areas of the TWHI land use classes as well as the area of native vegetation, domestic hayland and cropland are listed in Table 4. The summary of the digital Landsat data before and after resampling and filtering are listed in Table 5 a) and 5 b). The slight difference in total area is due to the cropping when the Landsat data was geometrically corrected. A comparison of the areas between the TWHI map and the Landsat data map is shown in Table 6. There is a close correlation between the two data sets. Cropland increased by 2% over the six years at the expense of native areas. However, some misclassification errors occurred in the satellite data analysis which explains part of this change. Early spring crops such as fall rye and winter wheat were actively growing when the satellite data was recorded and thus were confused with trees and shrubs.

Other known misclassifications which could have affected the calculation of the total area were clouds classified as saline areas and cloud shadows as waterbodies, thereby artificially increasing the waterbody class. This discrepancy is due to the fact that on the TWHI map only large semi-permanent and permanent waterbodies were mapped whereas in the Landsat classification all permanent, semi-permanent and temporary waterbodies above five acres in size were mapped. This inclusion of small wetland areas increased the waterbody class and decreased the native vegetation class. On the TWHI map these small waterbodies were included in the native vegetation class. The Landsat data were obtained on June 3 when large numbers of potholes containing water were present. In comparison, the TWHI map was based on aerial photography taken in July and August when a number of the potholes had dried up.

5. CONCLUSIONS AND EVALUATION

5.1 Costs

An initial period of training and familiarization was required before analysis could commence. After selection of appropriate analysis techniques, actual mapping of WMZ 22 took comparatively little time. All aspects of the demonstration project costs are summarized as follows:

Person Hours:		
Training	=	48 hours
Familiarization	=	178 hours
Fieldwork	=	60 hours
Project Work	=	63 hours
		349 hours
Direct Costs:		
Flying for the field check ?		$693.00
Travel expenses		$349.00
Transparencies		$143.00
CCT tape		$528.00

5.2 Benefits

The data produced in the form of a map and aerial measurements of cover classes was obtained with a speed and accuracy that far surpasses the more traditional manual air photo interpretation method. Lack of current air photo coverage and the prohibitive expense of acquiring new coverage makes this method even more cost, manpower and time effective.

5.3 Problems

Problems associated with this method are the inability to discriminate between tree and shrub communities, confusion between spring crops and woody vegetation, and cloud, cloud shadow problems. Cloud-free imagery is not always available during the critical spring period of the year when data is required. Before leaf out, trees and shrubs cannot be identified while after crops have emerged confusion between trees and shrubs and crops occurs. The time period when imagery must be obtained can therefore vary from year to year depending on leaf out and crop emergence. If cloud-free imagery is not available for the current year, data from a previous year must be considered. However, since the TWHI maps are relatively recent, using Landsat data from three or four years ago is not acceptable at the time.

If Landsat data for the entire Wynyard map sheet had been analysed a greater diversity of physiographic regions and soil types would have been encountered when phenological differences in time of leaf flush and crop emergence. It would have been necessary to map each physiographic unit separately and then mosaic the maps together. This would have taken additional time to complete.

The map, as produced for this report, has a Universal Transverse Mercator (UTM) grid on it. Since all roads are on a mile-grid, interpretation and location of units could have been improved with a different grid system.

5.4 Map Utility

The habitat types as produced on the map, have not yet been utilized by government departments or agencies. Mass production of the map, with a suitable grid and topographic reference points would ensure greater distribution and usage.

5.5 STEP Evaluation

The training of each individual principal investigator in the use of image analysis system, in the authors case, seemed feasible at first, but proved to be unrealistic and involved a major expenditure of time. Also work on the system on weekends, evenings and holidays was sometimes counterproductive since STEP advisors were not always available for consultation espe-

cially during the earlier learning stages of the program. Only simple tasks which had previously been explained and understood could be implemented. Weekday computer time had to be booked two to three months in advance which was sometimes a difficult situation for a long-distance commuter.

6. RECOMMENDATIONS

Based on the results of this report the following recommendations are made:

1. The land use types produced from Landsat data replace the old TWHI maps which currently have extensive usage.
2. Since short-term data on the rate of habitat loss in particular area is needed, it is recommended that simple overlay method of a Landsat colour transparency and checking the current condition of the native vegetation be investigated.
3. A computer operator work with the principal investigator to eliminate the learning time required for the principal investigator.
4. The Wildlife Branch review its objectives if a replacement through the use of Landsat data, of the TWHI map is required or merely to revise the rate of habitat loss.
5. If a replacement of the TWHI map is required, the pilot project, with modifications and more staff must be continued.

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Saskatchewan
Tourism and
Renewable Resources

Wildlife Research Division
Terrestrial Wildlife Habitat Inventory

WYNYARD 72-P

PRESENT LAND USE
Air photo interpretation and mapping by
G.L. Gradin
1981

DESCRIPTIVE LEGEND

The land use was classified using 1970 LIFT aerial photographs and updated by selective use of 1978 1:56,000 photos. The five land use classes are defined according to the proportion of total area supporting native vegetation and introduced perennial forage crops. In classes 1-4, the ratio of native vegetation to introduced perennial forage crops is at least 3:1, except where otherwise indicated by letters representing subclasses. Class 5 units are not subclassified.

For the purposes of this classification, land includes uplands plus wetlands which are temporarily inundated.

CLASS 1 90-100% of the land supports native vegetation and/or introduced perennial forage crops. The remaining 0-10% is used to produce annual crops, and/or for other purposes not entailing native vegetation or introduced perennial forage crops.

CLASS 2 50-90% of the land supports native vegetation and/or introduced perennial forage crops. The remaining 10-50% is used to produce annual crops, and/or for other purposes not entailing native vegetation or introduced perennial forage crops.

CLASS 3 30-50% of the land supports native vegetation and/or introduced perennial forage crops. The remaining 50-70% is used to produce annual crops, and/or for other purposes not entailing native vegetation or introduced perennial forage crops.

CLASS 4 10-30% of the land supports native vegetation and/or introduced perennial forage crops. The remaining 70-90% is used to produce annual crops, and/or for other purposes not entailing native vegetation or introduced perennial forage crops.

CLASS 5 0-10% of the land supports native vegetation and/or introduced perennial forage crops. The remaining 90-100% is used to produce annual crops, and/or for other purposes not entailing native vegetation or introduced perennial forage crops.

SUBCLASSES

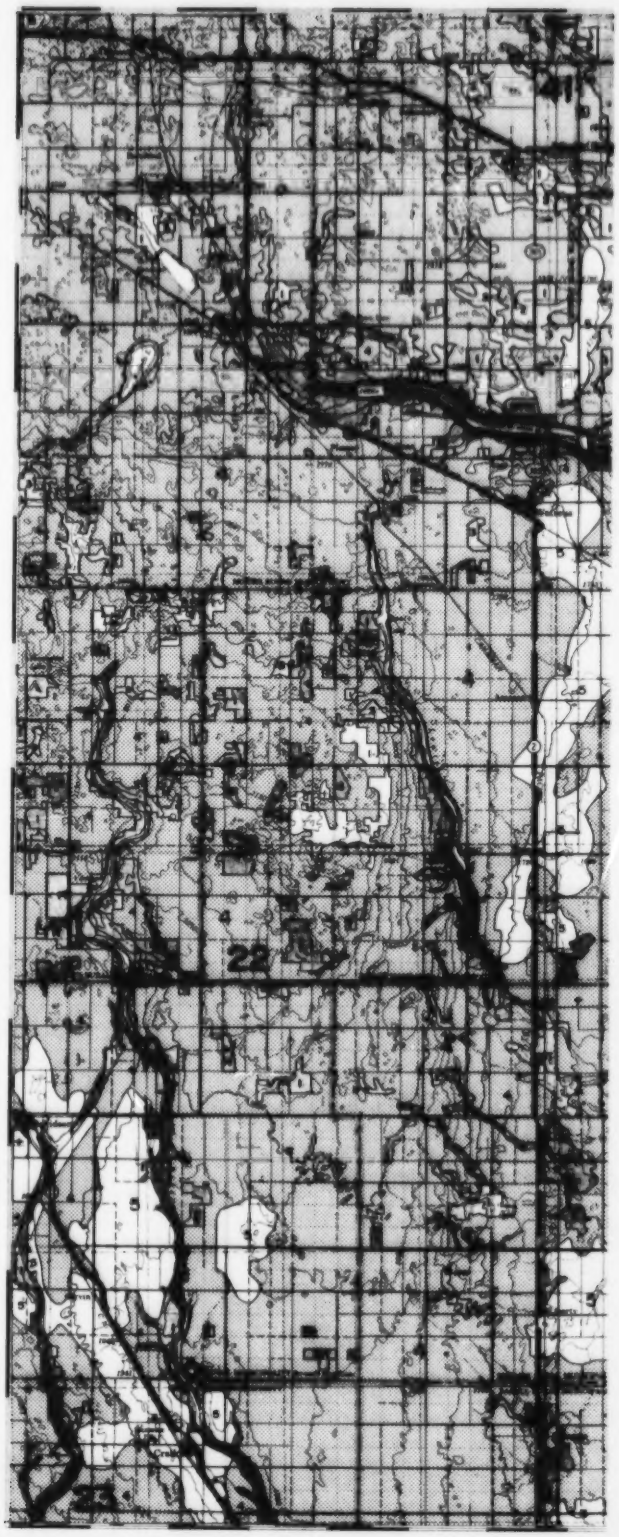
N-T The ratio of native vegetation to introduced perennial forage crops is less than 3:1 but at least 1:1.

T-N The ratio of native vegetation to introduced perennial forage crops is less than 1:1 but at least 1:3.

T The ratio of native vegetation to introduced perennial forage crops is less than 1:3.

EXAMPLE

2-N-T The class (2) indicates an area of land comprised of 50-90% native vegetation and introduced perennial forage crops. The subclass (N-T) indicates the ratio of native vegetation to introduced perennial forage crops is at least 1:1 but is less than 3:1.



Map 1. TWHI Land Use Map - Wynyard Map Area.